



Mars Science Opportunities in 2001/2003

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EGS
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MSP'01 Science



The Role of 2001 Lander Science in the Mars Program

- Explore ancient highland area to learn about early Mars climate.
- First chance to determine mineralogy of surface rocks and soils *in situ*.
- Demonstrate use of integrated instrument package to characterize surface materials for sample selection.
- First microscopy capability at Mars: soil grains and rock weathering morphology for sedimentary history.
- Synergy of orbital and surface instruments (mini-TES/THEMIS/TES; MARIE orbital and surface; MARDI/THEMIS/MOC)
- Characterize surface environment suitability for future robotic outposts and human exploration.
- Demonstrate in situ production of propellant.



MSP'01 Science



The Role of 2001 Orbiter Science in the Mars Program

- **Global map of elemental abundance**
 - **Hydrogen abundance map indicates near-surface water**
- **Global map of mineralogy**
 - **300 m resolution to find evaporites or minerals with biologic potential for sample return site selection**
- **Color imaging at 20 m resolution**
- **Characterize Mars radiation environment for future human exploration**



Science Objectives



- Globally map the elemental composition of the Martian surface, and determine the abundance of hydrogen in the shallow subsurface
- Acquire high spatial and spectral resolution maps of surface mineralogy
- Acquire high spatial resolution images of surface morphology
- Provide “nested” high spatial resolution descent imaging of the landing site
- Determine the nature of local surface geologic processes from surface morphology
- Determine the spatial distribution and composition of surface minerals, rocks, and soils surrounding the landing site. Extend this knowledge to the surrounding region by correlating orbital with lander and rover data.
- Characterize the Martian surface radiation environment as related to radiation-induced risk to human explorers; characterize specific aspects of the Mars near-space radiation environment that will complement measurements made on the Martian surface.
- Characterize the Martian soil and dust, including physical properties, oxidation properties, and chemical and mineralogical properties.
- Assess, through in situ experimentation, the feasibility of producing useable propellants from the indigenous Martian atmosphere.



Payload Assignments



- **The Mars Surveyor Program 2001 Payload Is Assigned to the Flight System Elements as Follows:**
 - **The orbiter science payload shall consist of:**
 - **Gamma Ray Spectrometer (GRS)**
 - **Thermal Emission Imaging System (THEMIS)**
 - **Mars Radiation Environment Experiment (MARIE)**
 - **The lander science payload shall consist of:**
 - **Elements of: Athena Precursor Experiment (APEX)**
 - **Mars Descent Imager (MARDI)**
 - **Mars Radiation Environment Experiment (MARIE)**
 - **Mars Environmental Compatibility Assessment (MECA)**
 - **Mars ISPP (In-situ Propellant Production) Precursor (MIP)**
 - **The rover science payload shall consist of:**
 - **Alpha/Proton/X-ray Spectrometer (APXS) - Part of APEX**
 - **Imaging Sensor System (ISS)**



MSP2001 Lander Science Payload



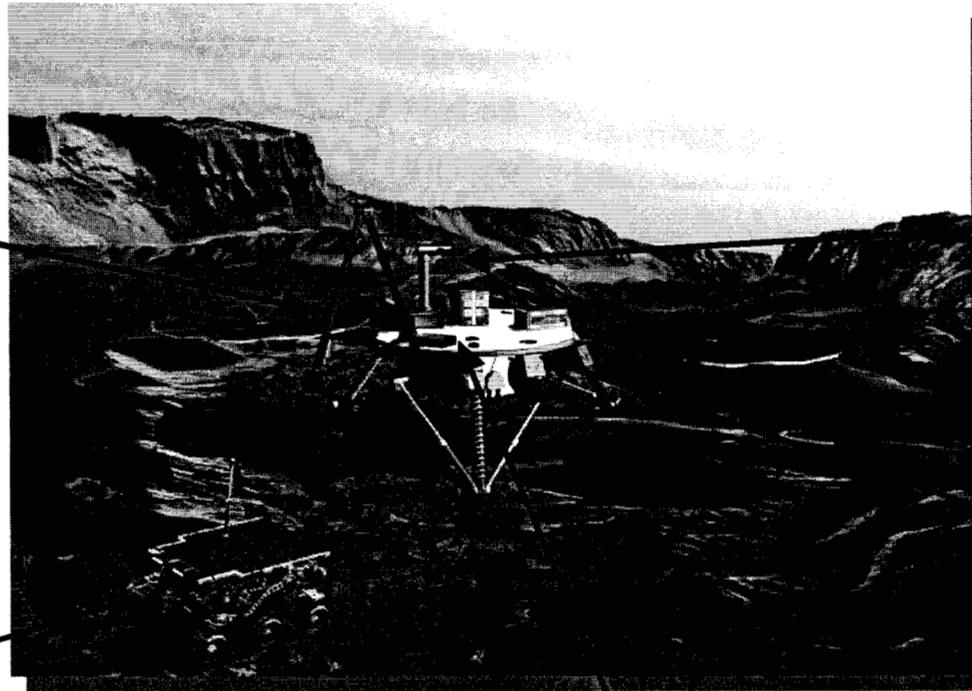
APEX (Athena Precursor Experiment)

MIP (Mars In-Situ Propellant Production)

MECA (Mars Environmental Compatibility Assessment)

MARIE (Martian Radiation Environment)

Robotic Arm with **Camera**,
Scoop,
Electrometer
and
Mössbauer Spectrometer



APEX Pancam
stereo, multi-spectral
imager. Bore-
sighted with **Mini-
TES** Emission
Spectrometer. Cal
and magnet targets.

Marie Curie Rover
with **APXS**
Elemental
Analyzer,
Cameras, and
**Dust
Electrostatic
Experiment**

**MECA Soil Wet
Chemistry,
Microscopy, and
Patch Plates**

MIP with **DART** Dust
Experiment and
MATE



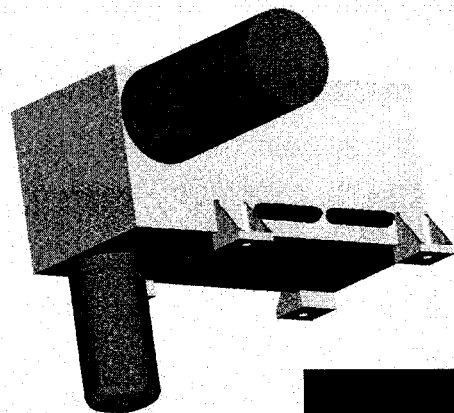
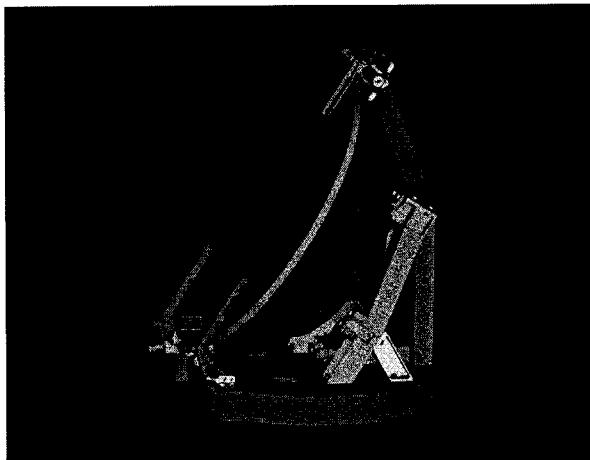
2001 Rover Mission Objectives



- **Contribute to the scientific exploration of the '01 landing site through:**
 - calibration of the APXS on Mars
 - imaging soil and rocks using rover cameras
 - acquire APXS measurements of soil and rock to establish groundtruth for PanCam / MiniTES
- **Contribute to future operations development by establishing:**
 - rover control interface to MSOP / LMA
 - integrated rover control and imaging toolsets for rapid image processing
 - interface between distributed science planning and operations
 - as a goal, use lander based PanCam images to update rover position knowledge
 - as a goal, traverse back to a specified location near the lander to demonstrate a sample return maneuver.
- **Contribute to education and public outreach:**
 - Planetary society / science team cooperation which involve students in mission

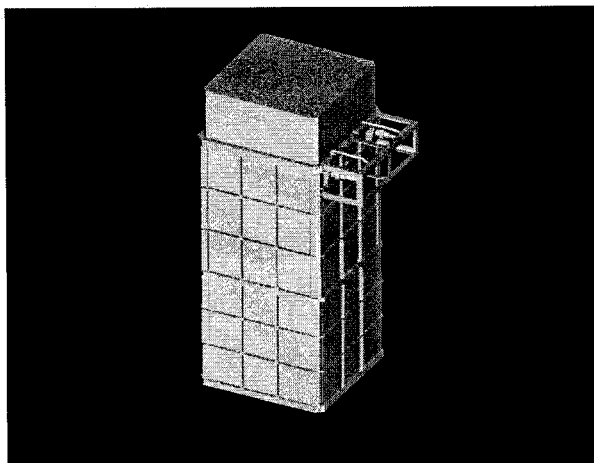
Gamma-Ray Spectrometer (GRS)

**Gamma
Sensor Head**



**High Energy
Neutron
Detector**

**Neutron
Spectrometer**



OBJECTIVES: Full planet mapping of elemental abundance with an accuracy of 10% or better and a spatial resolution of about 300 km, by remote gamma-ray spectroscopy, and full planet mapping of the hydrogen (with depth of water inferred) and CO₂ abundances by remote neutron spectroscopy

SCIENCE TEAM: PI is William Boynton. Co-I's are James Arnold, Peter Englert, William Feldman, Albert Metzger, Steve Squyres, Jacob Trombka, Heinrich Waenke, (Claude d'Uston-TBD). HEND PI is Igor Mitrofanov.

SUPPLIERS: U of Arizona, LANL, A.D. Little, Eurisys Measures (France), and IKI (Russian Space Research Institute). Hop Bailey is Instr. Mgr.

HARDWARE: GRS sensor head with 85 K cooler, neutron spectrometer (NS), & high energy neutron detector (HEND). Cooler FOV = 170°. Energy range is 0.2 to 16 MeV. CPU = 386.

INTERFACE: Mass = 30.1 kg. Power = 27.6 W. Volume = 48 dia. x 26 cm gamma sensor head, 13 x 13 x 29 cm NS, 27 x 22 x 19.2 cm HEND. Data rate = 2.5kbsp. 100°C annealing. 6 m boom. S/C materials usage requirements

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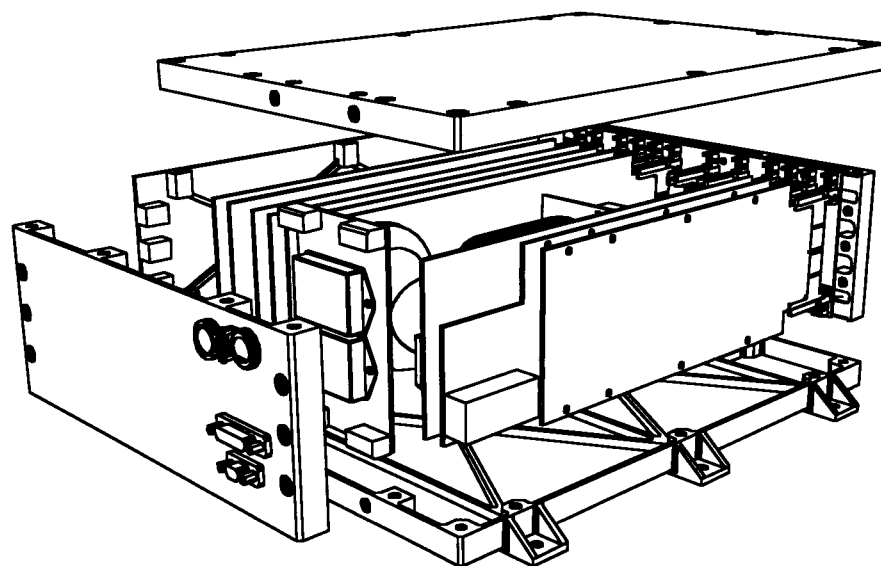
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Martian Radiation Environment Experiment (MARIE)



MARIE ORBITER



OBJECTIVES: Orbiter MARIE - Characterize specific aspects of near-space radiation environment, characterize the surface radiation environment as related to radiation-induced risk to human exploration, and determine and model effects of the atmosphere in an attempt to predict anticipated doses and assess its radiobiological effectiveness.

SCIENCE TEAM: PI is Gautam Badhwar (JSC).

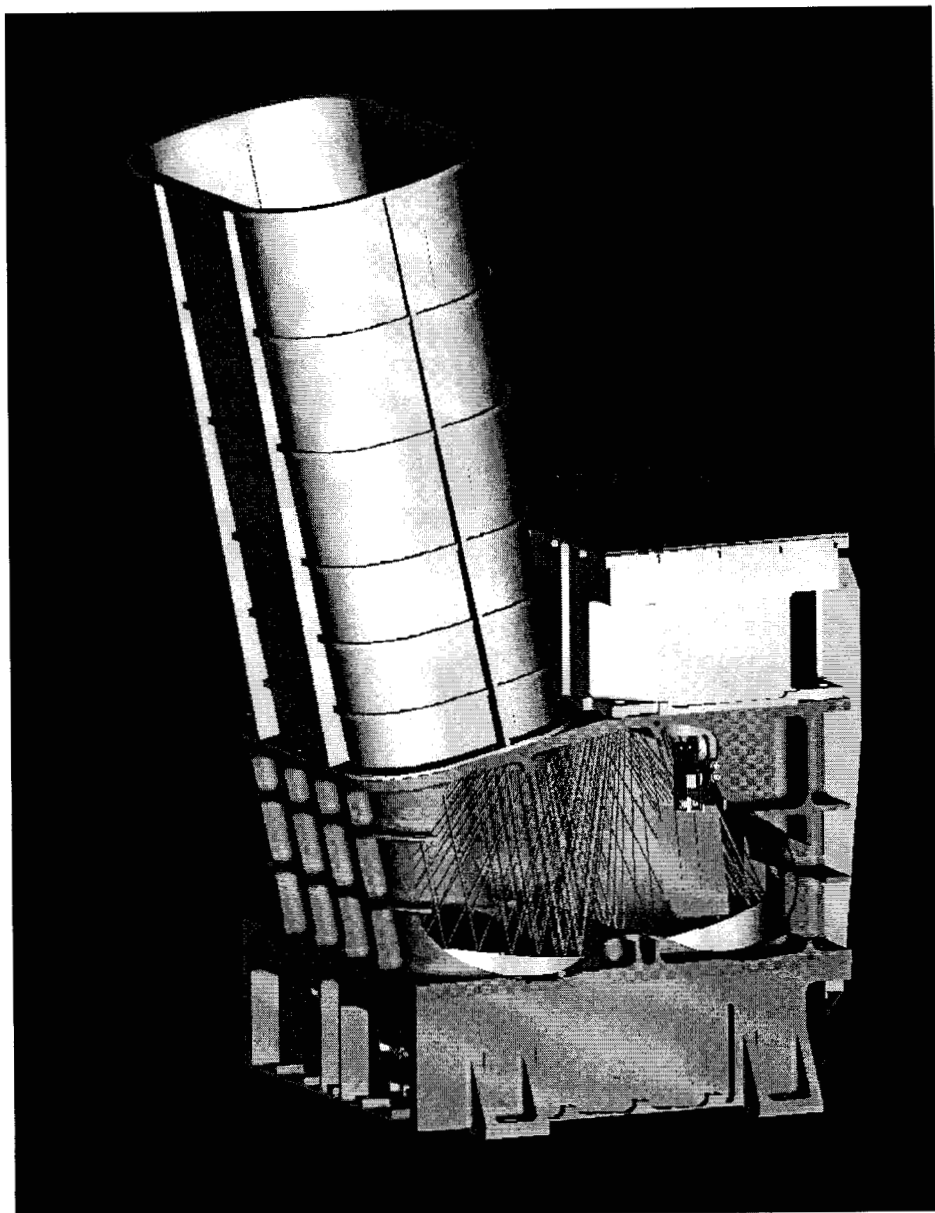
SUPPLIERS: JSC. Robert Dunn is the Instrument Manager. Subcontractors are Lockheed Martin and Battelle Pacific Northwest.

HARDWARE: Energetic particle spectrometer, 56° FOV, 2 silicon detectors 25.4 x 25.4 mm, 120 MB flash memory, Intel processor. Measures SEP events from 15 to 500 MeV/nucleon.

INTERFACE: Mass = 4.0 kg. Power = 7 W. Volume = 10.8H x 29.4L x 23.2Wcm. Data rate is 3 Mbits per day over RS-422 low speed data line.



Thermal Emission Imaging System (THEMIS)



OBJECTIVES: Determine the mineralogical composition of the surface for minerals whose abundance is approximately 10% or greater and at spatial scales of approximately 100 m. Provide information on the morphology of the surface such that features significantly less than 100 m can be adequately resolved.

SCIENCE TEAM: PI is Philip Christensen (ASU). Co-I's are Bruce Jakosky, Hugh Kieffer, Mike Malin, Harry McSween, and Kenneth Nealson.

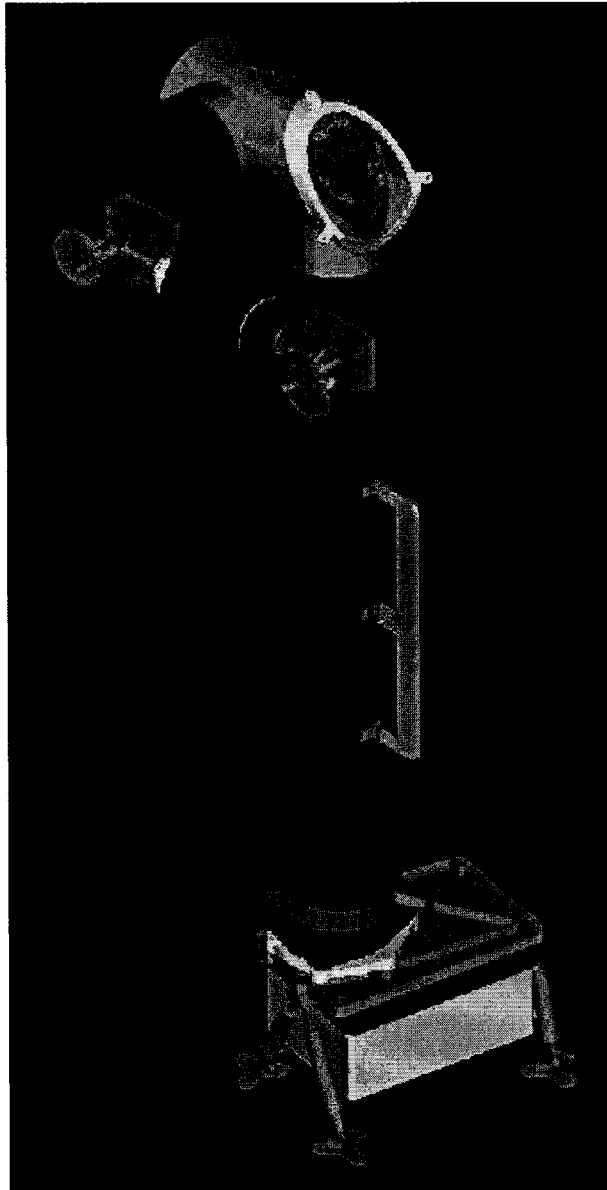
SUPPLIERS: Arizona State U, SBRS, MSSS. Greg Mehall is the Instrument Manager.

HARDWARE: Multi-spectral IR imager, visible imager (M98 heritage), 3 mirror, 20 cm focal length, f/1.7 anastigmat telescope, 4.6° (along track) by 3.5° (downtrack) IR FOV, 2.9° x 2.9° Vis FOV. Resolution = 80 m (IR) and 20 m (VIS). Spectral Range = 6.5 to 15.5 μ (IR) and 0.425 to 0.8 μ (Vis). Detectors are 320 x 240 pixels (IR) & 1024 x 1024 pixels (VIS).

INTERFACE: Mass = 12.8 kg. Power = 17 W. Volume = 55.8L x 37.9H x 28.0W cm. Uses 2 high speed RS-422 data lines.



APEX - PanCam/Mini-TES & Mössbauer Spectrometer



PanCam & Mini-TES

OBJECTIVES: Assess the geologic history, climatic history, and biological potential of the landing site, provide high-resolution color stereo images of the scene around the lander, determine the mineralogy of rocks and soils around the lander, & determine the mineralogy of the magnetic portion of martian dust.

SCIENCE TEAM: I - Steven Squyres (Cornell).

Co-I's are R. Arvidson, J. Bell, M. Carr, P. Christensen, D. Des Marais, T. Economou, S. Gorevan, L. Haskin, K. Herkenhoff, G. Klingelhofer, A. Knoll, J. Knudsen, M. Malin, H. McSween, R. Morris, R. Rieder, M. Sims, L. Soderblom, H. Wanke, T. Wdowiak. Barry Goldstein is the Project Manager.

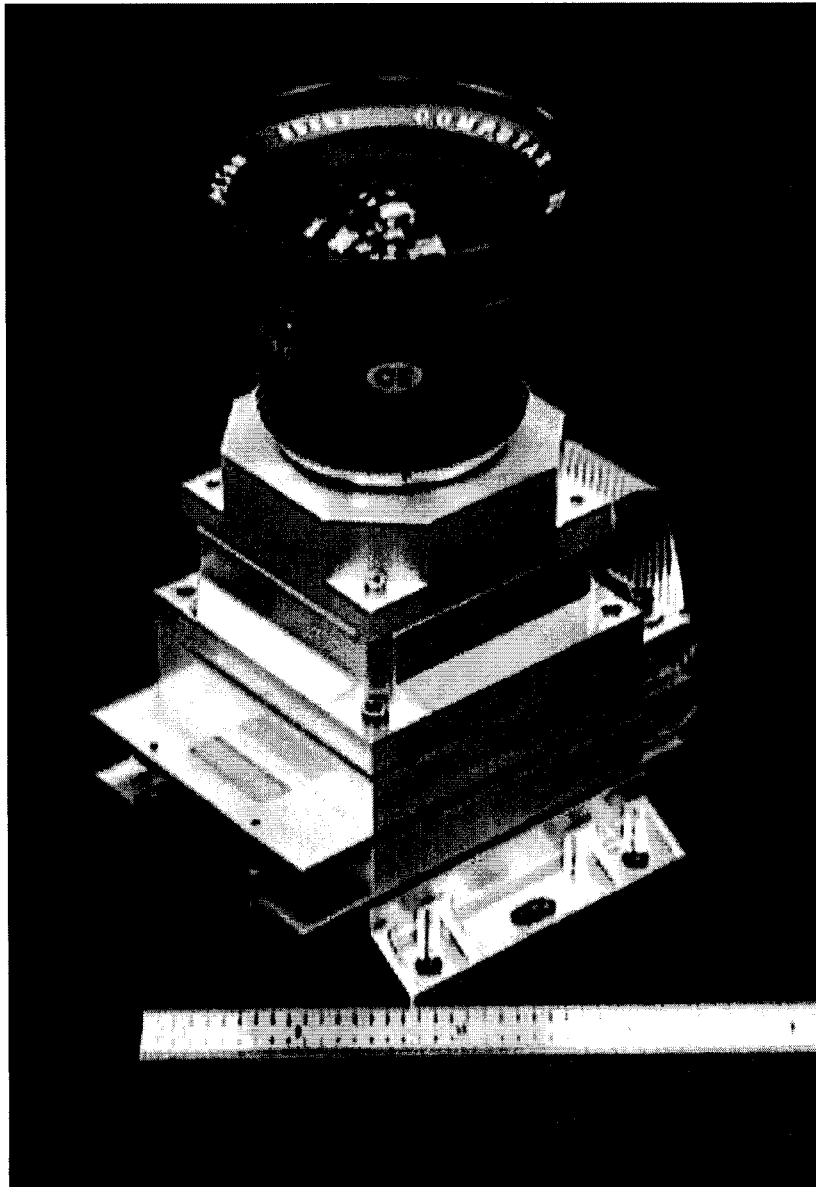
HARDWARE: Includes an infrared spectrometer with spectral range of 5-40 μm , a stereo multispectral imager (0.4 to 1 μm) with an angular resolution of 0.28 mrad/pixel, and a Mössbauer Spectrometer on the Robotic Arm with magnet target. The APXS is part of APEX but located on the Rover. Also supplies Payload Electronics Box (PEB) for Lander instruments.

INTERFACE: Mass = 18.5 kg. Needs 2 high speed and 2 low speed RS-422 data lines. Uses lander CPU and software. Includes targets for PanCam, Mini-TES, and Mössbauer.

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Mars Descent Imager (MARDI)



OBJECTIVES: Characterize the geology of the landing site and provide geologic context for collected samples. Determine the nature of local surface geologic processes from surface morphology, and provide a link between local and regional geologic processes, and provide images (>20) for nearby Rover traverses.

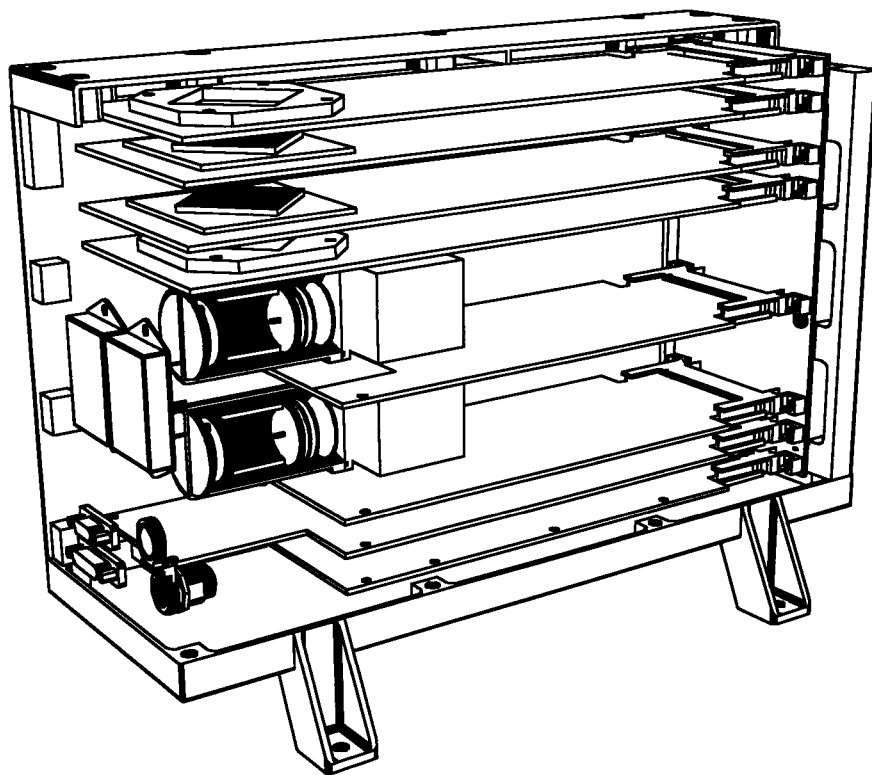
SCIENCE TEAM: Team Leader is Mike Malin (MSSS). Team Member is Ken Herkenhoff.

SUPPLIERS: MSSS and TBD optics supplier. Mike Ravine is the Instrument Manager.

HARDWARE: This is a M98 build to print MARDI - Panchromatic camera, 9 element f/2 optics, focal length of 7.135 cm, 73.4° FOV, 500 to 800 μ spectral range, resolution of 12.5 cm/pixel @ 100 alt., 5:1 nesting, using 1024 x 1024 pixel CCD @ 8 bits/pixel with compression of <2:1. Processor is Motorola DSP56166 @ 30 MIPS.

INTERFACE: Mass = 0.52 kg. Power = 5W. Volume = 8 x 8 x 12.7 cm. Utilizes a high speed RS-422 data line and the S/C computer for data processing.

MARIE LANDER



OBJECTIVES: Lander MARIE - Measure the accumulated absorbed dose and dose rate in tissue as a function of time, determine the radiation quality factor, determine the energy deposition spectrum from 0.3 keV/ μ m to 1000 keV/ μ m, and separate the contribution of proton, neutrons, and HZE particles to these quantities.

SCIENCE TEAM: PI is Gautam Badhwar (JSC).

SUPPLIERS: JSC. Robert Dunn is the Instrument Manager. Subcontractors are Lockheed Martin and Battelle Pacific Northwest.

HARDWARE: Energetic particle spectrometer with two 24 x 24 position sensitive detectors followed by 2 proportional counters 1.78 dia x 1.78 cm (TEPC & CPC), 56° FOV, 60 MB of flash memory, and an Intel processor. Measures the linear energy transfer range of 0.3 to 1000 keV/ μ m in 512 channels.

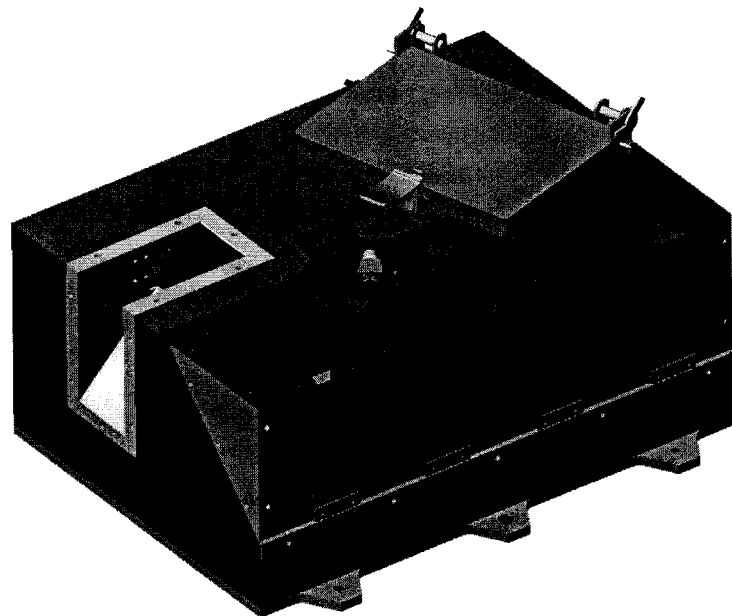
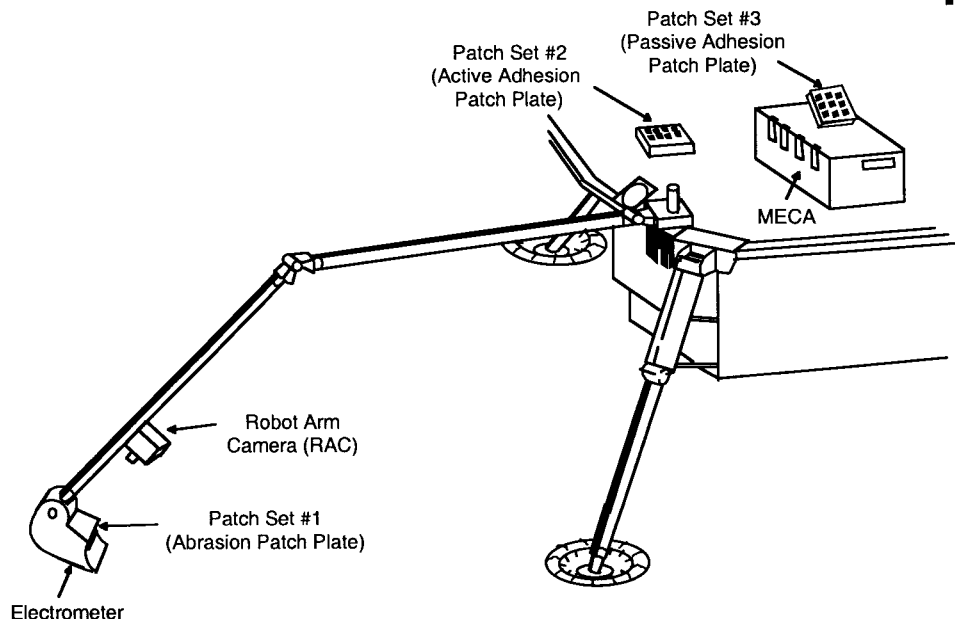
INTERFACE: Mass = 4.0 kg. Power = 6.8 W. Volume = 15.8W x 34.3L x 23.7H cm. Data rate is <8 Mbits per day over RS-422 low speed data line. Contains 2 - 0.9 μ Curie alpha sources and 2 - 40 torr propane vessels (proportional counters).

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Mars Environmental Compatibility Assessment (MECA)



OBJECTIVES: Characterize dust and soil (size, shape, adhesion, and abrasion), identify undesirable and harmful interactions with human explorers and associated hardware systems, and support the design of extravehicular activities & habitation systems.

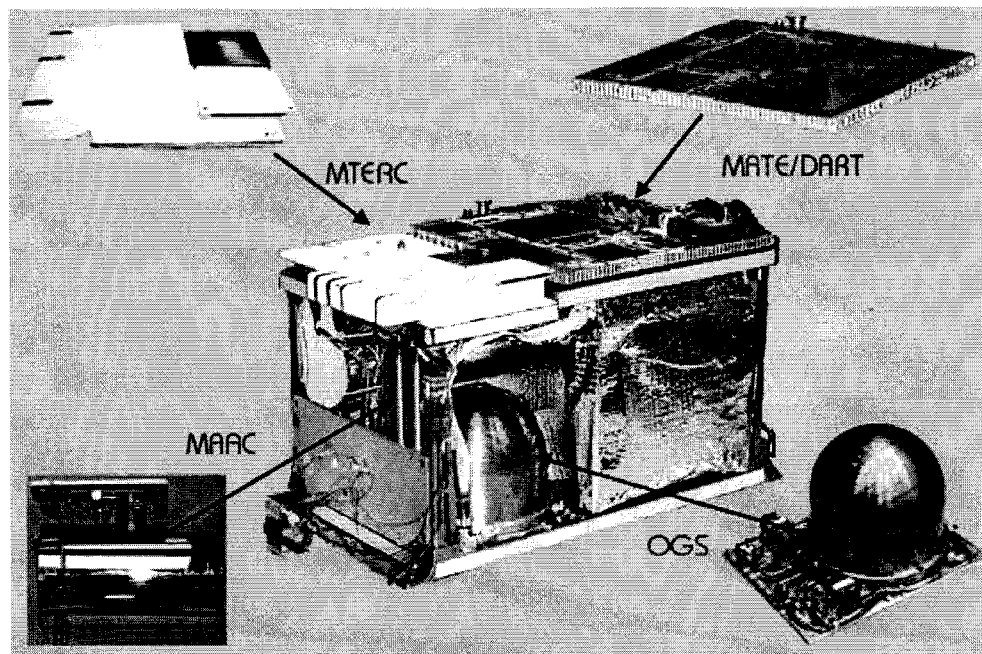
SCIENCE TEAM: PI is Thomas Meloy (W. Virginia U). Co-I's are Michael Hecht, Mark Anderson, Steve Fuerstenau, Thomas Pike, Wayne Schubert, Martin Frant, Peter Smith, Horst Uwe Keller, Wojtek Markiewicz, John Marshall, Calvin Quate

SUPPLIERS: JPL, Max Planck, U of Arizona, and Stanford. Michael Hecht is the Instrument Mgr. Joel Rademacher is the System Engineer.

HARDWARE: 4 integrated instruments = Atomic force microscope, optical microscope, electrometer and a wet chemistry laboratory. Also includes a sample wheel and 3 patch plates.

INTERFACE: Mass = 10 kg. Power = 5 W. Volume = 27W x 37L x 15H cm deployed, plus patch plate and Mössbauer target mounted on top. Uses 1 RS-422 low speed data lines. Needs the robotic arm for soil samples, the robotic arm camera, and the camera's redundant electronics.

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OBJECTIVES: Demonstrate operation of critical in-situ propellant production (ISPP) subsystems and process in the Mars environment. Characterize aspects of the Mars surface environment which will impact ISPP operations.

MIP TEAM: PI @ JSC is Dave Kaplan. Jim Ratliff is the instrument manager.

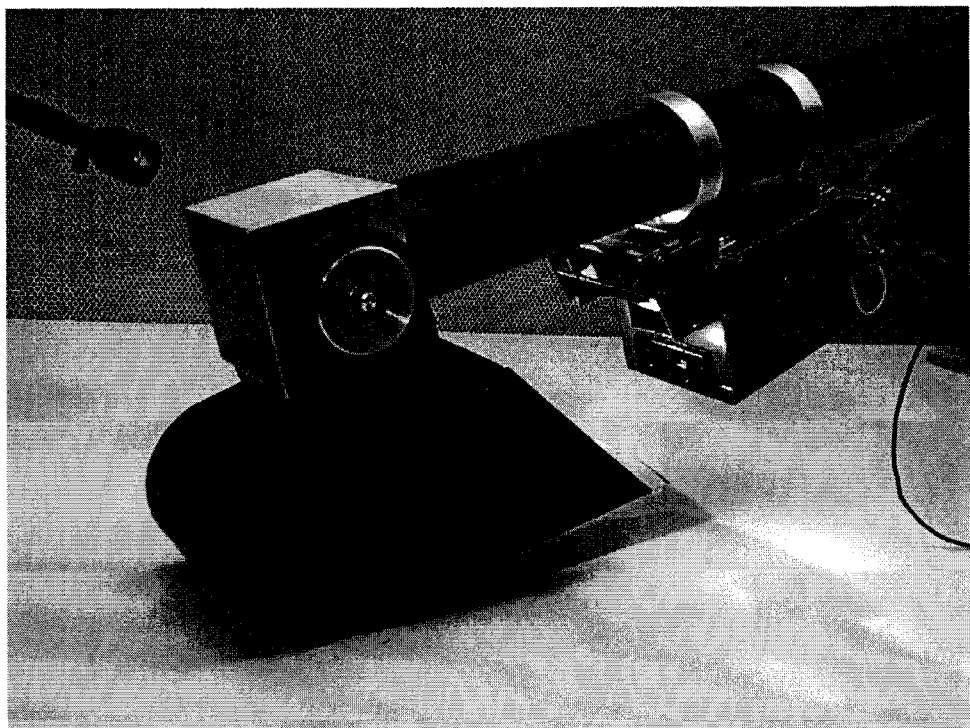
SUPPLIERS: JSC, JPL, LeRC, & Lockheed Martin. Jim Ratliff is the instrument manager.

HARDWARE: MIP includes 5 integrated instruments:

- DART** - Dust Accumulation and Removal Test
- MAAC** - Mars Atmosphere Acquisition and Compression
- MATE** - Mars Array Technology Experiment
- MTERC** - Mars Thermal Environment/Radiator Characterization
- OGS** - Oxygen Generating Subsystem

INTERFACE: Mass = 8.5 kg. Peak Power is 15W. Power Night is 3W. Volume = 45.4L x 25.4W x 31.1H cm. Desires 140° FOV (+Z) for the MTERC and DART.

OBJECTIVES: Imaging support for the MECA patch plates, Rover deployment, RA digging, and obtaining MECA soil samples.

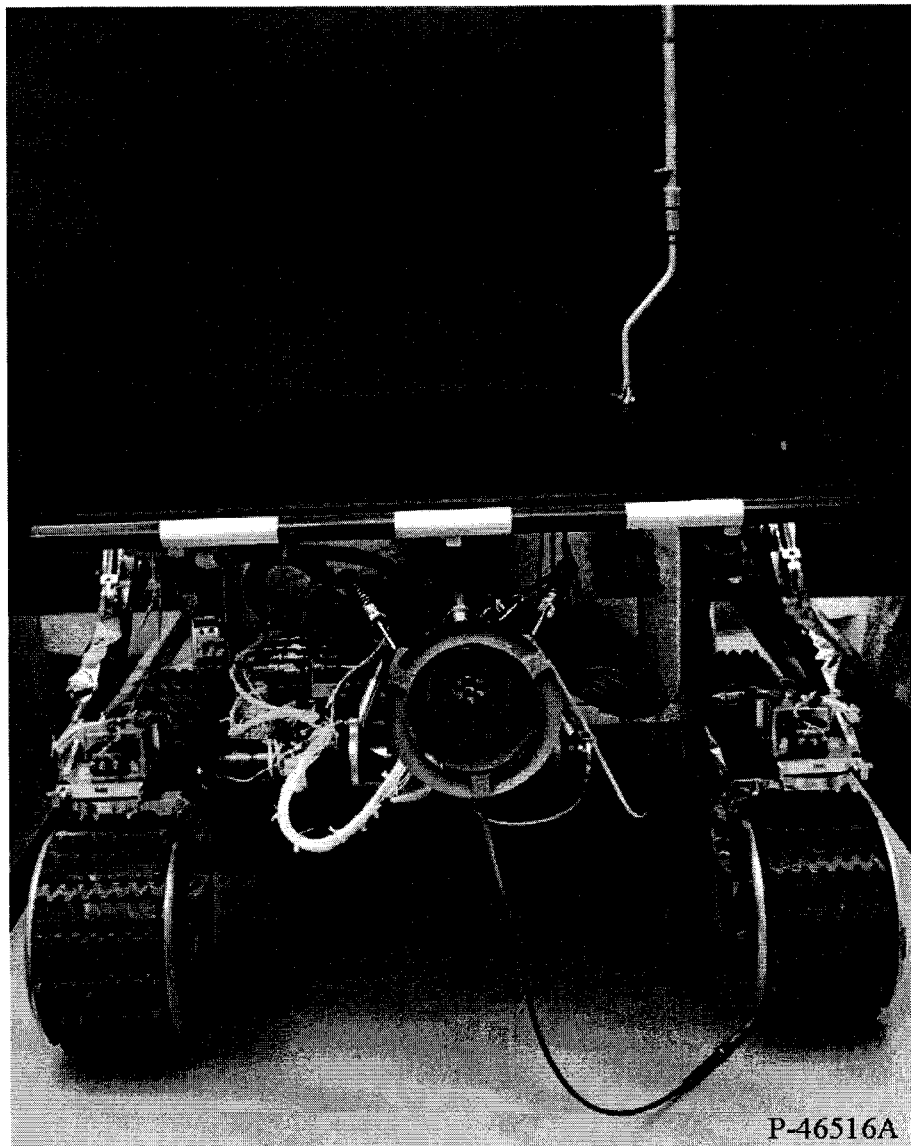


RAC TEAM: Project Manager is Peter Smith. Robert Reynolds is the instrument manager.

SUPPLIERS: University of Arizona and Max Planck Institute (MPI).

HARDWARE: Camera head supplied by MPI. FOV is $25^{\circ} \times 50^{\circ}$ at infinity. Active focus with 12.5 mm focal length lens @ f/12. Focus range for objects at distances from 11 mm to infinity. On board leds provide red/green/blue illumination. Exposure times from 0.5 to 32 seconds, with a 2 second readout time. Electronics, located in the payload electronics box (PEB), also provide support to the MECA microscopic imager. Uses 512 x 256 pixel frame transfer CCD with 23 micron pixel spacing. Camera head and electronics are largely M98 build to print.

INTERFACE: Mass = 1.83 kg. Camera head mounts near end of robotic arm.



- **OBJECTIVES:** The APEX Alpha Proton X-ray Spectrometer (mounted on the Rover) will determine elemental chemistry of surface materials for most major elements except hydrogen. The approach used is to expose material to a radioactive source that produces alpha particles with a known energy, and to acquire energy spectra of the alpha particles, protons and X-Rays returned from the sample.
- **SCIENCE TEAM:** I - Steven Squyres (Cornell). Co-I's are R. Arvidson, J. Bell, M. Carr, P. Christensen, D. Des Marais, T. Economou, S. Gorevan, L. Haskin, K. Herkenhoff, G. Klingelhofer, A. Knoll, J. Knudsen, M. Malin, H. McSween, R. Morris, R. Rieder, M. Sims, L. Soderblom, H. Wanke, T. Wdowiak. Barry Goldstein is the Project Manager.
- **HARDWARE:** This elemental composition instrument consists of alpha particle sources and detectors for back-scattered alpha particles, protons and X-Rays. The APXS sensor head is mounted external to the Rover chassis on a deployment mechanism. This mechanism places the APXS in contact with rock and soil surfaces. The APXS electronics are mounted within the rover, in a temperature-controlled environment. Mass = 16.0 kg



MSP '01 Orbiter

The Mars Surveyor 2001 Orbiter is scheduled for launch on March 30, 2001. It will arrive at Mars on Oct. 20, 2001, if launched on schedule. After a propulsive maneuver into a 25-hour capture orbit, aerobraking will be used over the next 76 days to achieve the 2-hour science orbit. Aerobraking was utilized on the Mars Global Surveyor and Mars Climate Orbiter missions. The Orbiter will carry 3 science instruments, the Thermal Emission Imaging System (THEMIS), the Gamma Ray Spectrometer (GRS), and the Mars Radiation Environment Experiment (MARIE). THEMIS will map the mineralogy and morphology of Martian surface using a high-resolution camera and a thermal infrared imaging spectrometer. The GRS will achieve global mapping of the elemental composition of the surface and determine the abundance of hydrogen in the shallow subsurface. The GRS is a rebuild of the instrument lost with the Mars Observer mission. The MARIE will characterize aspects of the near-space radiation environment as related to the radiation-related risk to human explorers. It will be used in conjunction with a similar instrument on the '01 Lander to determine and model the effects of the atmosphere on the radiation-induced hazard on the surface. The 2001 Orbiter will also support communication with the '01 Lander scheduled to arrive on Jan. 22, 2002.

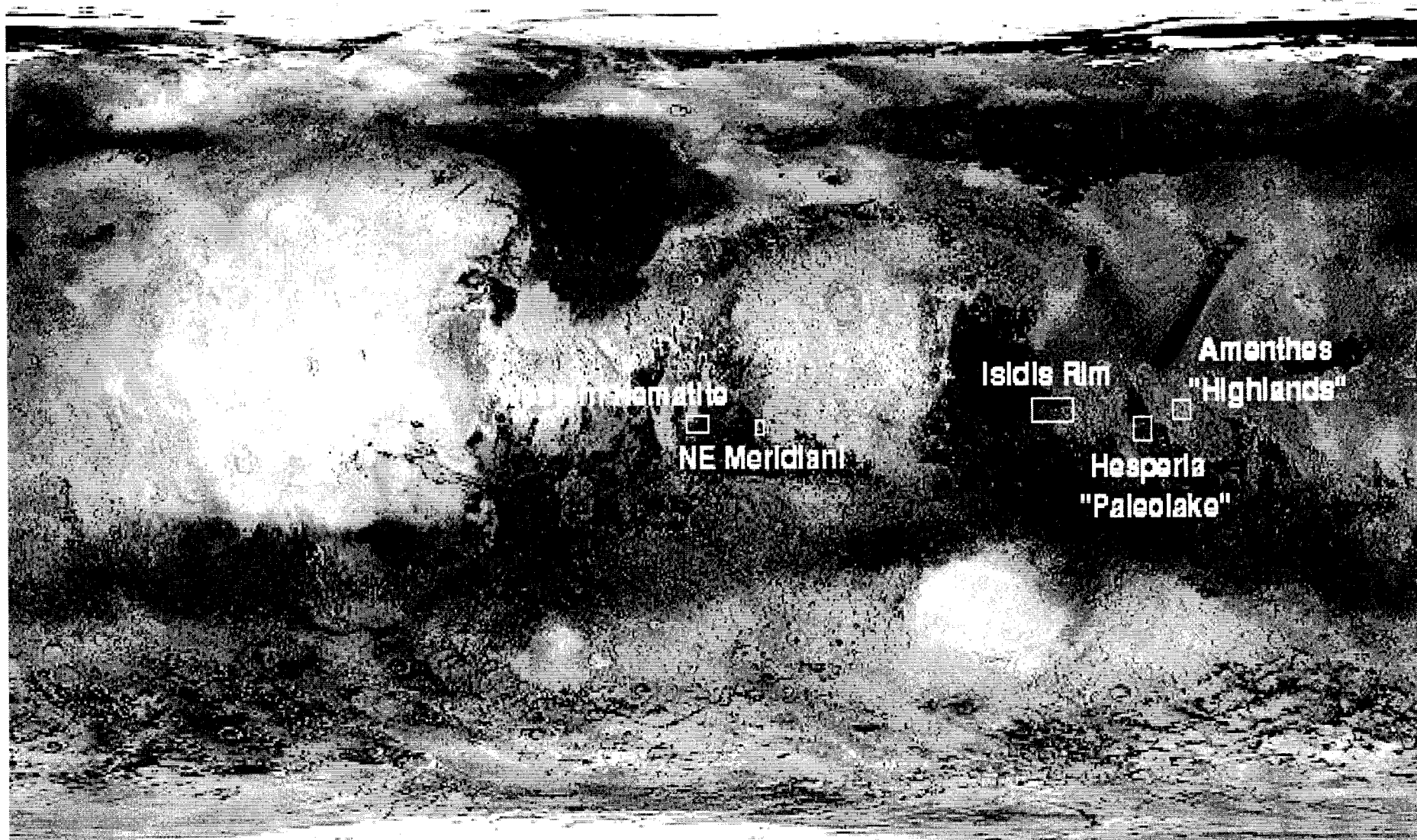


MSP '01/'03 Lander



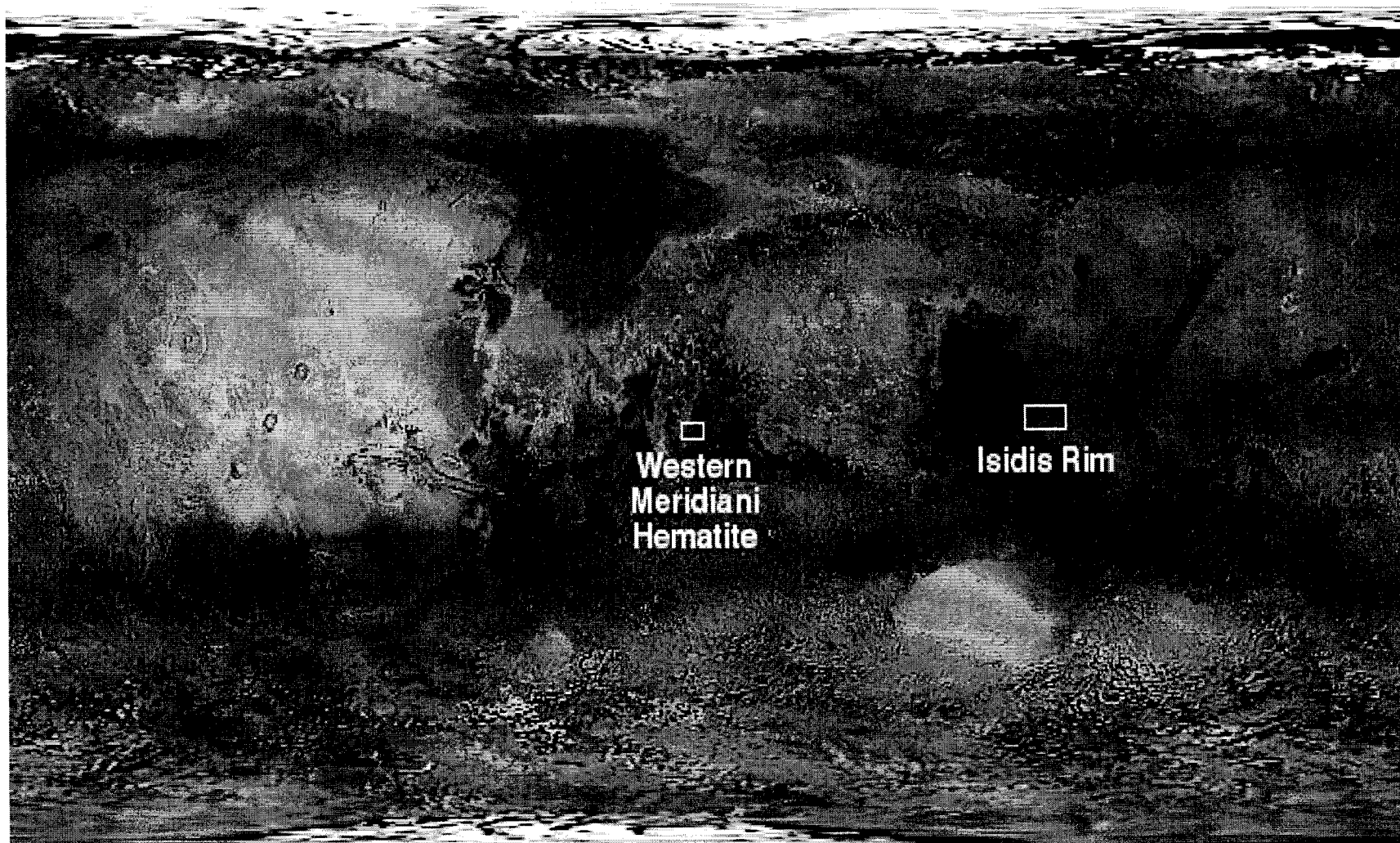
The Mars Surveyor 2001 Lander was originally scheduled for launch on April 10, 2001 and to land on Mars on Jan. 22, 2002. Because of the loss of the '98 Mars Polar Lander, doubt has been cast on the reliability of some unknown component(s) of that landing system and on the ability of the Project to meet the schedule to launch after all known problems and new communications requirements arising from the loss of the '98 Climate Orbiter (lack of com backup). Consequently, the '01 lander mission may be slipped to the 2003 opportunity. At this time, it is not known how much of the original payload could be accommodated in '03 after the lander is upgraded to make it more "hazard tolerant" and with the addition of direct-to-Earth communications and perhaps a flight recorder (so-called black box). With a payload consisting of MECA, Pancam-MiniTES and the robotic arm with its Moessbauer spectrometer, the 2001 Lander payload is ideal for characterizing soil and rock mineralogy. The descent imaging camera will provide images of the landing site for geologic analyses, and will aid planning for operations and traverses by the rover. The 2001 Lander will also be a platform for instruments and technology experiments designed to provide key insights for decisions regarding human missions to Mars. Experiments on the Lander will be used to demonstrate *in situ* rocket propellant production using gases in the Martian atmosphere. Other experiments will characterize the Martian soil properties and surface radiation environment.

Landing Site Selection

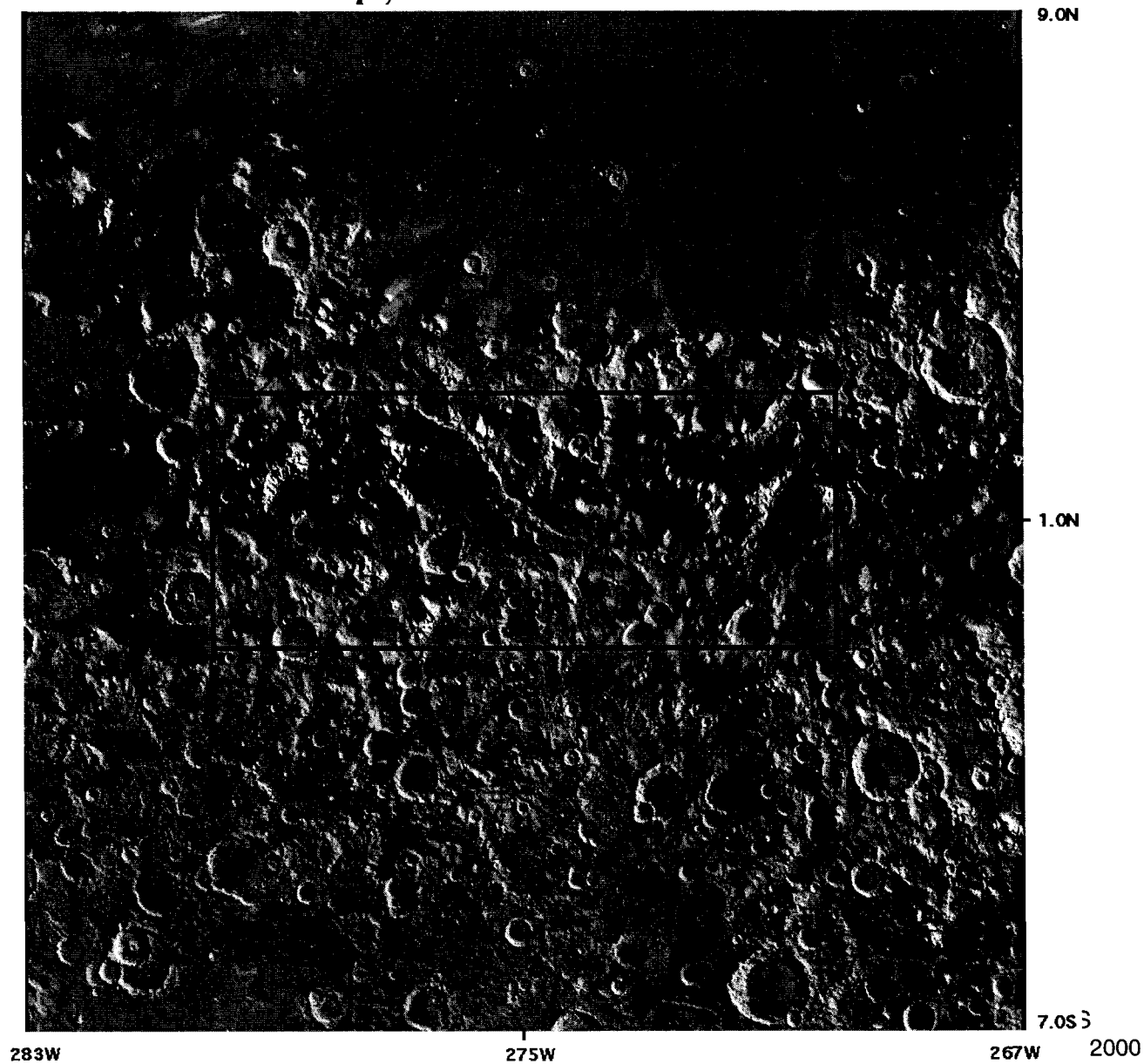


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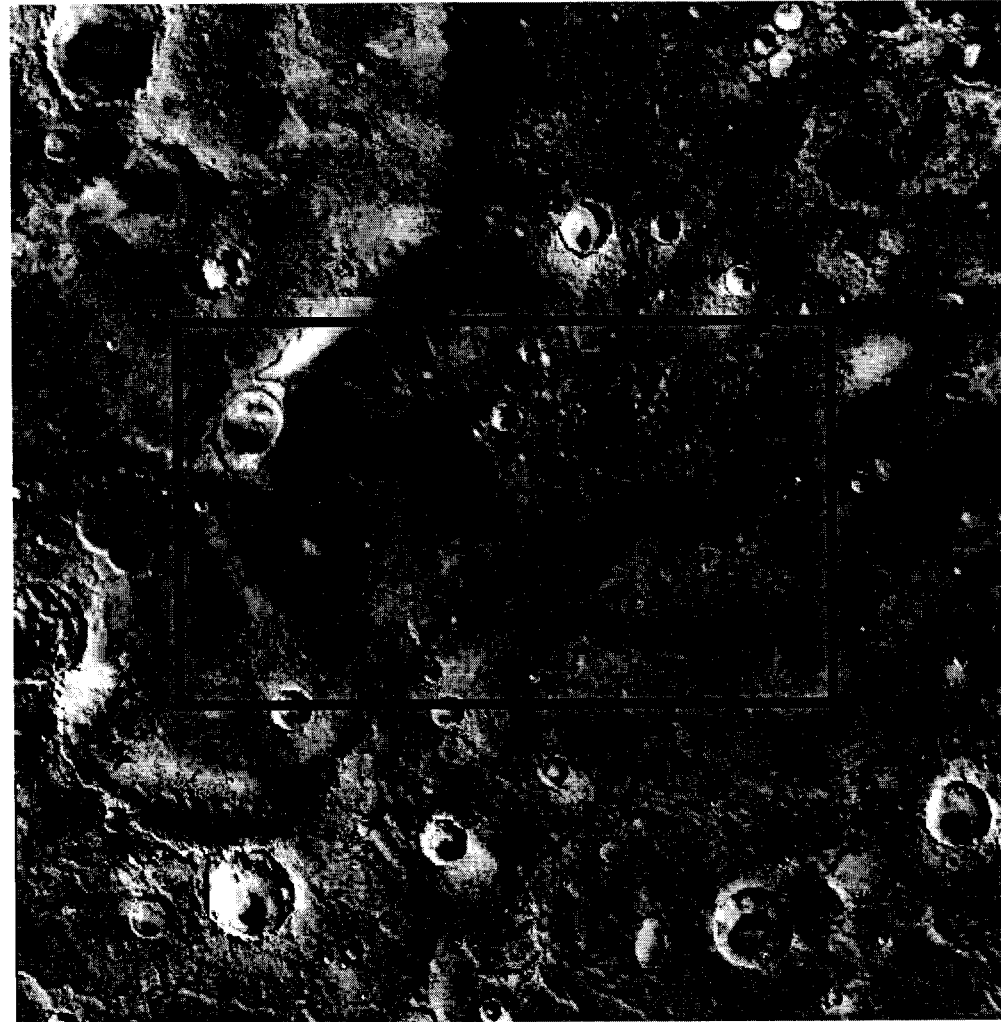
Landing Site Selection



Landing Site Selection



Landing Site Selection



2.5N

5.5S

8.5W

0.5W

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